AN INVESTIGATION OF THE RELATIVE IMPORTANCE OF THOSE VARIABLES AFFECTING THE TRAVEL OF A VESSEL AT LAUNCHING

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By

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Submitted in partial fulfillment of

the requirements for the degree of

Master of Science

in

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from the

Massachusetts Institute of Technology

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Cambridge, Massachusetts,

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Professor W. S. Newell
Secretary of the Faculty,
Massachusetts Institute of Technology,
Cambridge, Massachusetts

Dear Sir:

In accordance with the requirements for the degree of Master of Science in Naval Construction and Engineering we submit herewith a thesis entitled "An Investigation of the Relative Importance of Those Variables Affecting the Travel of a Vessel at Launching".

Respectfully,

ACKNOWLEDGEMENT

The authors wish to express their appreciation to those professors whose help was of such great value in the preparation of this thesis, Professor E. C. Holtsworth, Professor G. C. Manning, and Professor W. W. Robertson for assistance on launching details, and to Professor R. D. Douglass for his great help in preparation of the charts.

We also wish to express our deep appreciation to Captain W. McL. Hague, USN, under whom we served, and whose keen interest in the details of launching the USS ALABAMA, USS SHANGRI-LA, and other vessels, inspired us to pursue the subject as a major interest.

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SUMMARY

The object of this thesis is to determine the relative importance of those variables affecting the travel of a vessel at launching and to devise a rapid means of determining the point of ultimate travel by use of nomographic charts.

Since the functions of the variables which influence the ultimate travel of a vessel at launching are discontinuous, no single formula can be written that will yield the ultimate travel in a single solution. However, a recursion formula used in a step-by-step computation similar to those found in electrical engineering will yield an approximate curve of travel versus velocity, ultimate travel being denoted by the point at which the velocity becomes zero.

Inasmuch as the tediousness of the step-by-step method of calculation varies directly as the number of steps, but the accuracy also increases with the number of steps, a quick method of performing the operations is desirable. The five nomographic charts developed in this thesis accomplish this. There is no single chart that will solve the problem, since there exists no single equation able to do so. However, the charts have been found to reduce the time normally required by as much as four or five times, and thus are considered by the authors to be a quite satisfactory

method of solution. The method of construction of the nomograms devised in this thesis is found in the APPENDIX. It must be remembered that the accuracy of these charts in determining the point of ultimate travel cannot be greater than that of the assumed coefficients.

The results and conclusions have been obtained by successive launching calculations of a hypothetical ship having the same hull form as an ESSEX class aircraft carrier. The physical construction and peculiarities of the ways are those of the battleship ways in the Norfolk Naval Shipyard, since these are standard ways and the authors are familiar with their construction. By changing one variable at a time and holding all others constant, the families of curves found in the RESULTS were plotted. From these curves the authors conclude that: the net chain drag force has the greatest effect upon ultimate travel; the resultant increase in ultimate travel caused by a delay in the point of pickup of chain drags is less than the delay in the point of pickup; a change in the coefficient of grease friction (thus atmospheric temperature on the day of launching) or a moderate change in the combined weight of the vessel and cradle has little effect upon the point of ultimate travel; and a variation in the predicted height of tide has very little effect upon the point of ultimate travel.

The estimate of water resistance was obtained by using the curve of Keith's Coefficient, "C", of Water Resistance as found in Reference [1]. For comparison, a modified curve of Keith's Coefficient, "C", was constructed (Curve VI), keeping the area under the curve equal to that under the standard curve but increasing the float-off or 100% buoyancy value. Two calculations were made, one using the standard "C" curve, one using the modified curve. There was a discrepency of only twenty feet travel, indicating that when large drag forces are used, the shape of the "C" curve is somewhat immaterial. However, this float-off value of Keith's Coefficient "C" becomes increasingly important in determining the point of ultimate travel as the interval of completely waterborne travel is increased. It is, therefore, recommended that further investigation be made to determine more accurately the float-off or 100% buoyancy value of Keith's Coefficient, "C", of water resistance where this curve is to be used for launchings involving small net chain drag forces.

INTRODUCTION

More than once in the history of the art and science of shipbuilding, the person charged with the problem of launching a large vessel into restricted waters has suddenly realized that his knowledge of the effect of each of the variables involved on the ultimate travel is quite meagre. Generally, he has been unable to find an evaluation of these effects in the literature on launching.

In our modern text books on this subject, there are shown methods of analysis of launching data, but these presuppose that the vessel is already overboard. The launching designer must make his analysis <u>before</u> the vessel is waterborne.

Of the variables affecting ultimate travel, the following are considered of greatest importance:

1. Actual displacement of the vessel at the time of launch.
2. Coefficient of grease friction.
3. Coefficient of chain drag friction.
4. Weight of chain drags.
5. Point of drag pickup.
6. Height of tide.
7. Magnitude of water resistance.

Each of these variables has an effect upon the ultimate travel of the ship, some much greater than others. Those whose effect is relatively insignificant should be discarded for preliminary calculations. However, due to a general lack of literature on the subject to date, it is not known which variables to discard and which to consider seriously.

In general, it is found most feasible to consider that all these variables will combine in any single launching in at least two ways. They may all combine so that the travel will be a maximum, or so that it will be a minimum. If the maximum combination does not allow the vessel to travel too far or to strike the opposite shore, and if the vessel safely clears the way ends with an acceptable margin, the combination is deemed satisfactory, or at least, safe. Any other combination of these variables leads to a refinement in estimating total travel.

Any single calculation for total travel is tedious (an example is given in Table II in the APPENDIX), because it must be done as a step-by-step calculation. No equation yet devised will yield total travel from a given set of variables and from a single solution of the equation. Since the accuracy of the result is a direct function of the number of steps used, a nomogram quickly suggests itself as a rapid means of performing this step-by-step calculation.

In summarizing the considerations of the problem, it might be said that the ship must be transferred from the ways to the water, safely clearing the way-ends and coming to an economically short stop. It must be stopped before striking the opposite bank, and quickly so, to minimize the time required for the tugs to take it in tow and berth it. Also, a short run facilitates chain drag recovery and reduces the cost of the drag roadway installation. However, a long run is desirable to reduce cost of drag installation, to reduce chance of snapping drag wires, and to preclude any possiblility of the drags' preventing the vessel from clearing the ways without having wire tension draw it back up to the way ends. '

There are several methods of calculation presently employed. The Tobin method of integration has been proposed [2], but tends to be cumbersome. The energy equation is commonly used as well as the force equation. All of these methods are tedious unless a nomogram, or "alignment chart" is employed to reduce the number of steps.

It is the purpose of this thesis to develop such a nomogram, or series of them, and with their aid to analyze a launching rather exhaustively to determine the effects of the variables involved.

PROCEDURE

The procedure in estimating the ultimate travel is based on the "force equation" of Newton,

$$F = Ma \tag{1}$$

By integration, we get an expression

$$V_2^2 = \frac{1}{e^Q}\left[V_1^2 + \frac{CF_1(e^Q-1)}{B^{2/3}}\right] \tag{2}$$

Where $$e^Q = e^{\frac{2gK}{W}(S_2-S_1)} \tag{3}$$

B = Average buoyancy over the increment, in tons

C = Keith's water resistance coefficient

F_1 = Net downways force, in tons, exclusive of water resistance

V_2 = Velocity at the end of a given increment of travel, in ft./sec.

V_1 = Velocity at the beginning of a given increment of travel, in ft./sec.

Since the variables involved come into play at various times, this equation must be applied in a step-by-step manner, getting one value of V_2^2 from the previous value of V_1^2.

We find V_2^2 by using nomographic charts. Chart I is entered first to obtain the value of Keith's coefficient, "C". Next, with "C", "W", "B", and the increment of travel under consideration, enter Chart II to obtain e^a. ("e" = Napierian logarithm base)

To obtain the resultant downways force, exclusive of water resistance, we use Chart III, entering with the known or assumed variables (W-B), f_g, D, f_d. Where:

f_g = Coefficient of grease friction

f_d = Coefficient of chain drag friction

D = Weight of chain drags

We read the value of F_1 on its scale.

Next, we obtain the value of $\frac{F_1 C}{B^{2/3}}$ from Chart IV, by entering with values of "C" and "F_1", from Charts I and III respectively, and "B", which is known from the buoyancy curve.

The last step is to enter Chart V with the value of $\frac{F_1 C}{B^{2/3}}$ from Chart IV, the velocity at the beginning of the increment of travel under consideration, and the value of e^a obtained from Chart II. The value of V_2^2 is read, its square root taken, and thus we have the velocity of the vessel at the end of the increment in question. The foregoing procedure is followed, step by step,

until a negative value of V_2^2 is reached. The vessel stops in this last increment.

An approximation to the actual ultimate point of travel is made by straight line interpolation between the last positive value of V_2^2 and the first negative value. Where this straight line crosses $V_2^2 = 0$ is the ultimate point of travel.

Another method also can be used to determine the end point of travel. If we set $V_2^2 = 0$ in equation (2) and solve for S', the distance between the point of travel of the last positive value of V_2^2 and $V_2^2 = 0$, we get

$$S' = \frac{WC}{2gB^{2/3}} \operatorname{Log}_e \left[1 - \frac{B^{2/3} V_1^2}{F_1 C} \right] \qquad (4)$$

The accuracy of this last method is not considered justified, however, and the straight line interpolation is used in this thesis.

To use the charts, certain data are required. These include:

1. Buoyancy curve versus travel (generally drawn to determine way-end pressures, and based on weight of vessel alone), declivity of ways, height of tide, position of center of gravity of vessel and cradle, point of dropoff, etc.

2. Assumed values of

   a. Coefficient of grease friction, f_g

   b. Coefficient of chain drag resistance, f_d

   c. Curve of water resistance coefficient versus percent buoyancy afloat.

   d. Point of travel at which chain drags are picked up.

   e. Height of tide.

   f. Number and weight of chain drag clumps per side

   g. Size of increments of travel to be used in step-by-step velocity calculations

The assumptions made in using the force equation include the following:

1. Drag resistance coefficient is defined as ratio of the actual drag wire pull to the drag weight. Thus the "coefficient of friction" is modified by the angle of the wire relative to the ground, and acceleration of the drag itself. This angle is very small, however, and the discrepancy between "drag resistance coefficient" and "drag coefficient of friction" is not great.
2. Average buoyancy is used for the entire increment of travel and is assumed to have a constant value throughout the increment. Thus, the values of "C" and "F_1" are constants for each increment.

3. Floatoff, rather than dropoff, is assumed; thus no dissipation of energy is considered due to the bow's dropping off of the way-ends.

4. The cradle is assumed self buoyant, but its weight is included in ship's weight because it must be accelerated at the same rate as the ship itself.

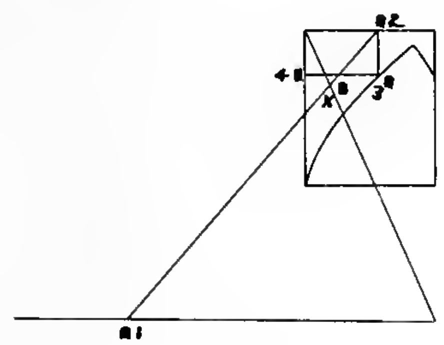
5. Keith's curve of "C" versus "% Buoyancy afloat" is assumed as a basis for water resistance chiefly because it is a standard which is available in a commonly used textbook [1]. This curve agrees closely with analyses of the launching of USS TARAWA and USS SHANGRI-LA.

6. All forces which accelerate or decelerate the vessel are assumed to act in the line of motion of the center of gravity of the ship and cradle. The true angle between lines of action of these forces and the tangent to the path of the center of gravity of ship and cradle is very small.

The design of Chart III provides for no camber of ways, and for 9/16" declivity. See APPENDIX, Page 42, for the method of plotting the coefficient of grease friction scale when a declivity different from 9/16" is used. In the event cambered ways are used, it is advisable to calculate the retarding force due to grease friction with a slide rule.

CHART I

— TO DETERMINE VALUE OF KEITH'S COEFFICIENT "C" —



- KEY -

EXAMPLE —

GIVEN:
"W" = 20000 TONS
"B" = 8400 TONS
REQUIRED:
TO DETERMINE "C"

1. DRAW A LINE FROM "B" = 20000 TONS TO "100 %" ON SCALE OF "PERCENT BUOYANCY AFLOAT", CROSSING INDEX LINE AT SOME POINT, X. FOR ALL VALUES OF "C" FOR A 20,000-TON SHIP, X WILL BE THE PIVOT POINT.
2. DRAW A LINE FROM "B" = 8400 TONS THROUGH X, TO "PERCENT BUOYANCY AFLOAT" SCALE.
3. PROJECT THIS POINT DOWN TO KEITH'S CURVE.
4. PROJECT THE INTERSECTION HORIZONTALLY TO THE "C" SCALE.
5. REQUIRED VALUE OF "C" = 610.

28 APRIL, 1946
R&R RHL

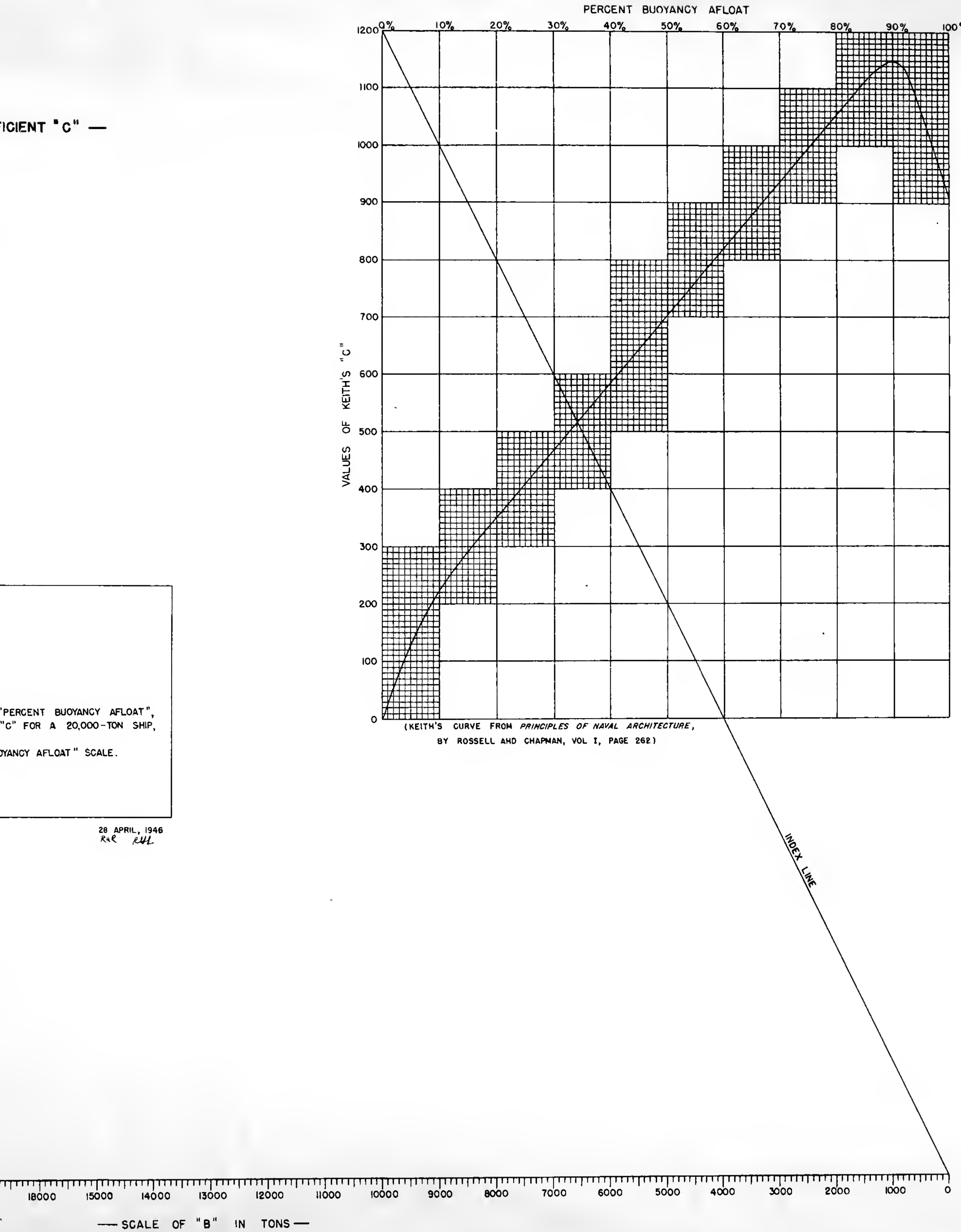


CHART II

— TO DETERMINE e^Q —

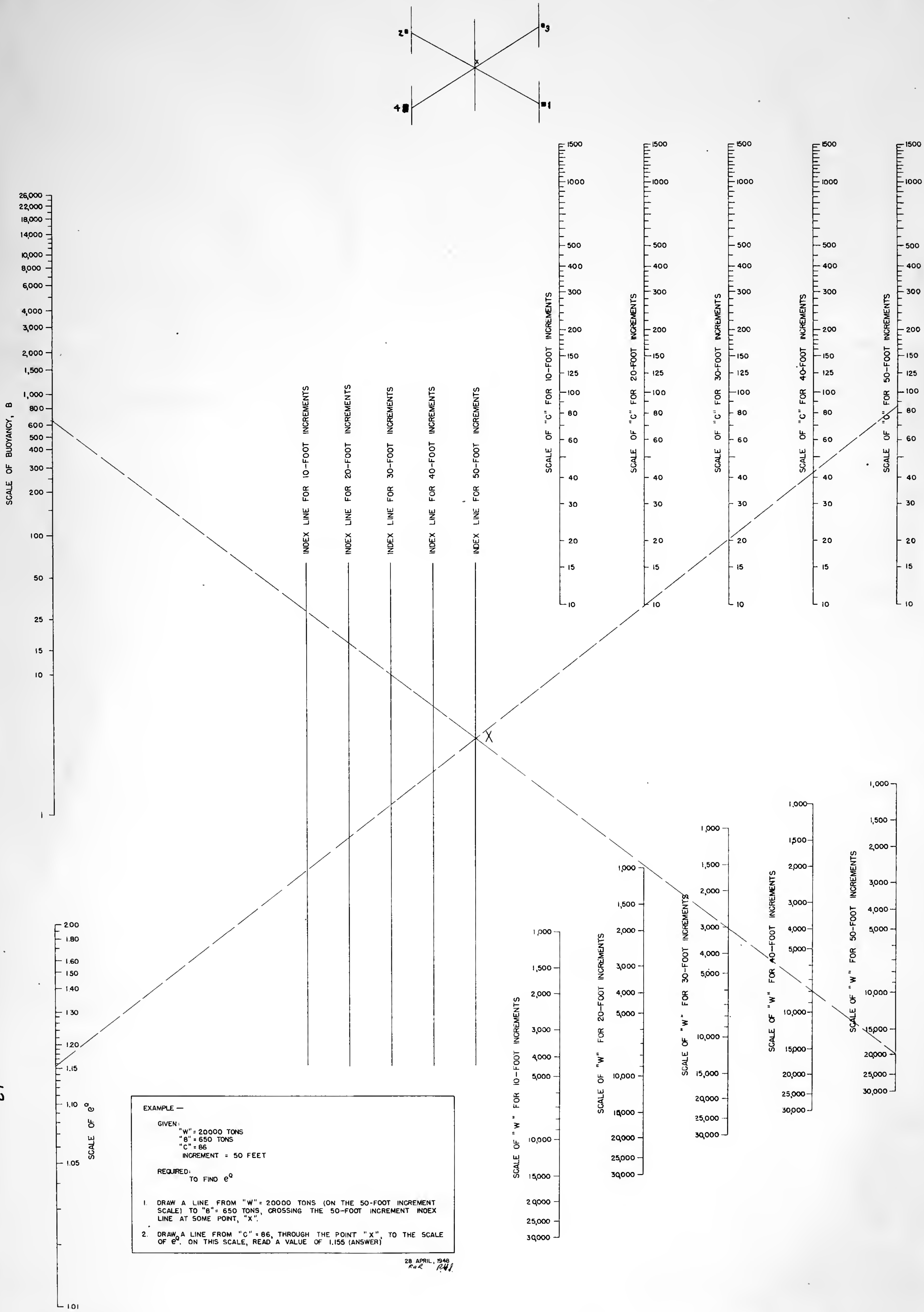
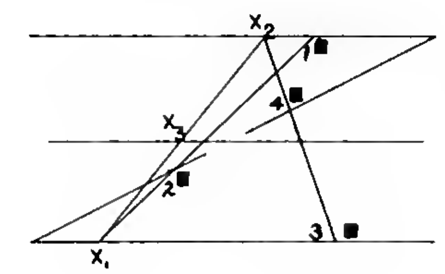
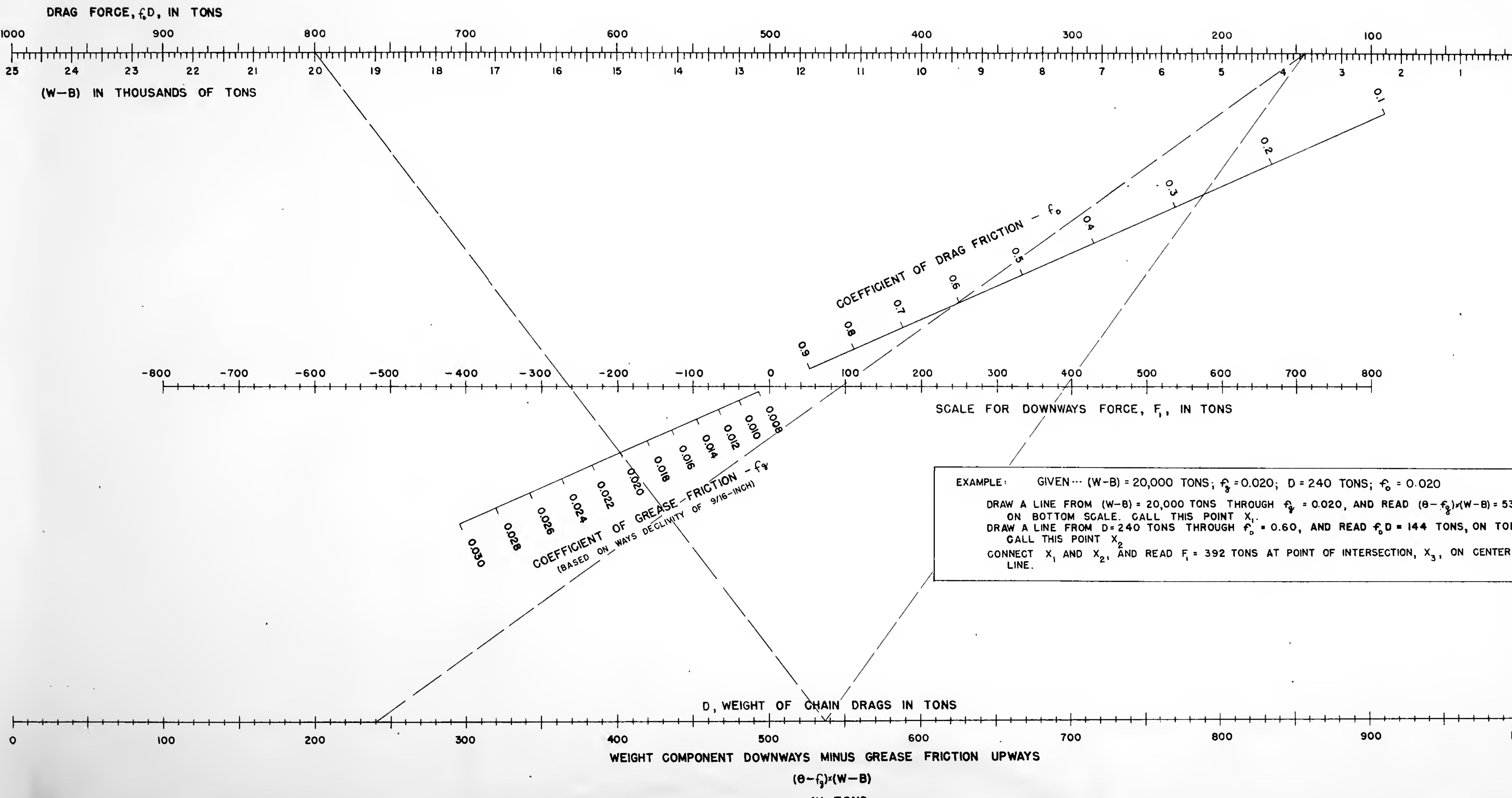


CHART III

— TO DETERMINE THE DOWNWAYS FORCE, F_1 —



- KEY -



EXAMPLE: GIVEN··· (W-B) = 20,000 TONS; f_g = 0.020; D = 240 TONS; f_o = 0.020

DRAW A LINE FROM (W-B) = 20,000 TONS THROUGH f_g = 0.020, AND READ $(\theta - f_g)\times(W-B)$ = 536 TONS ON BOTTOM SCALE. CALL THIS POINT X_1.

DRAW A LINE FROM D = 240 TONS THROUGH f_o = 0.60, AND READ $f_o D$ = 144 TONS, ON TOP SCALE. CALL THIS POINT X_2.

CONNECT X_1 AND X_2, AND READ F_1 = 392 TONS AT POINT OF INTERSECTION, X_3, ON CENTER PARALLEL LINE.

28 APRIL, 1948
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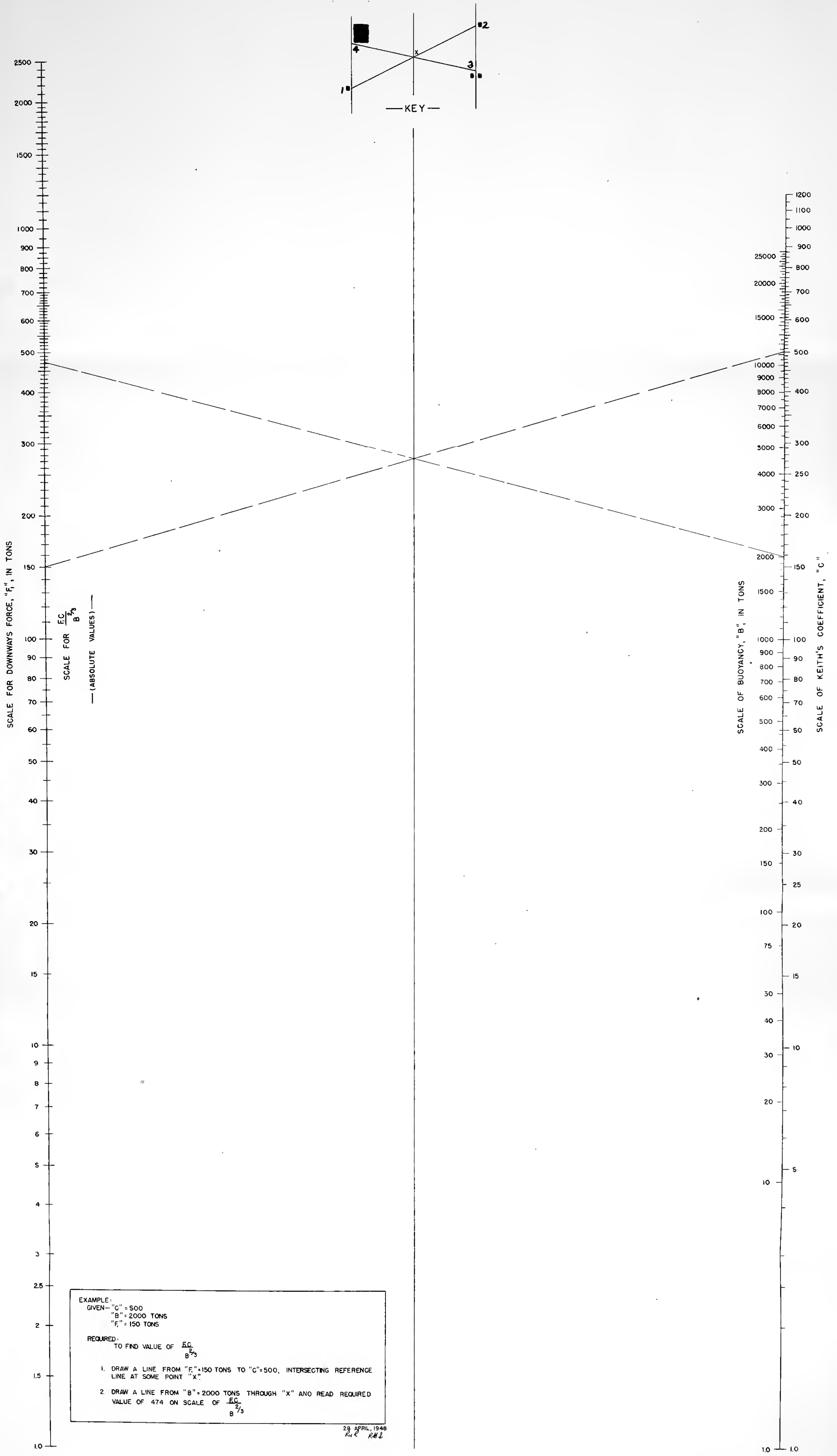
CHART IV

— TO DETERMINE $\frac{F\,C}{B^{2/3}}$ —



EXAMPLE:
GIVEN— "C" = 500
"B" = 2000 TONS
"F_1" = 150 TONS

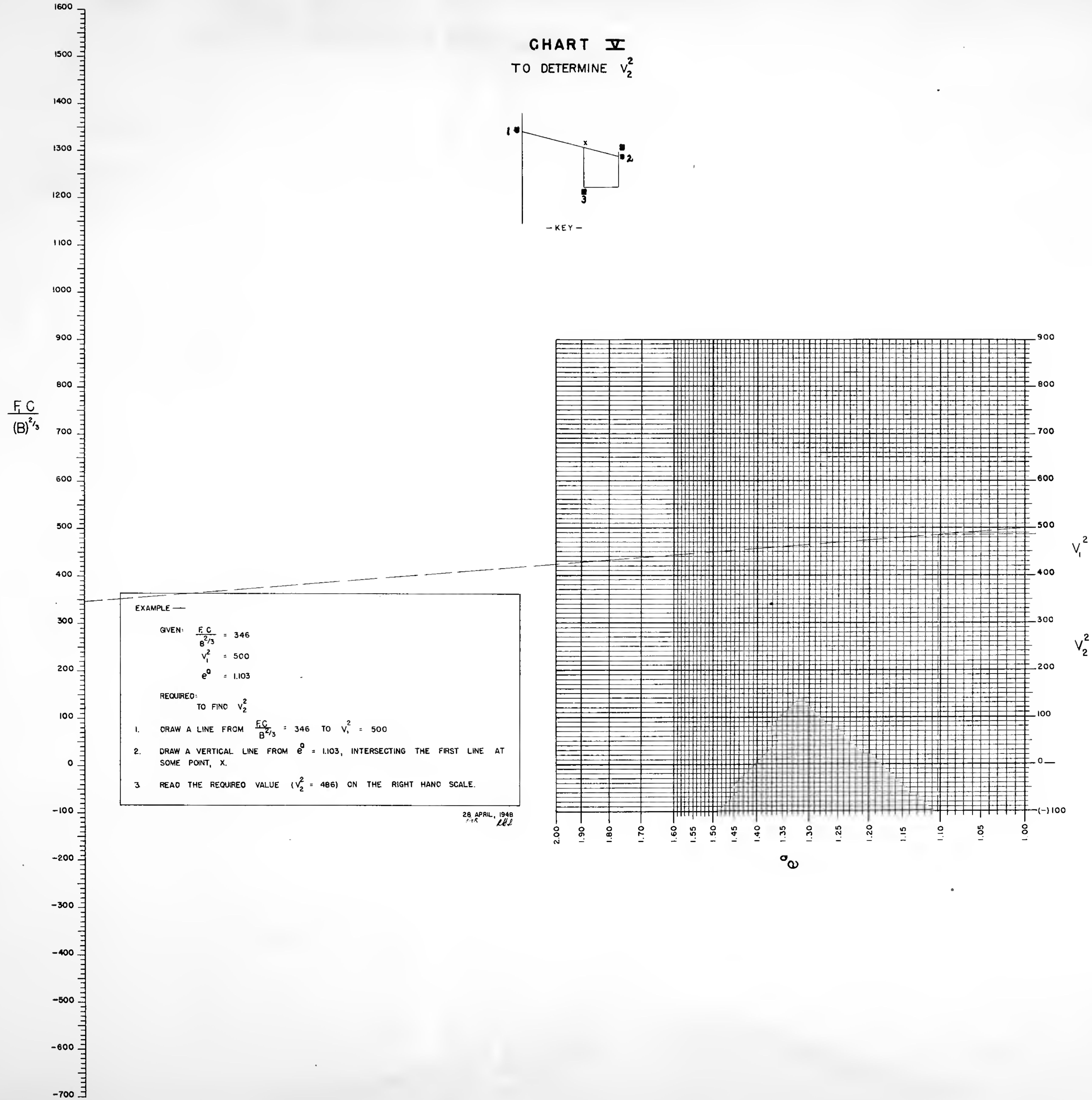
REQUIRED:
TO FIND VALUE OF $\frac{FC}{B^{2/3}}$

1. DRAW A LINE FROM "F_1" = 150 TONS TO "C" = 500, INTERSECTING REFERENCE LINE AT SOME POINT "X".
2. DRAW A LINE FROM "B" = 2000 TONS THROUGH "X" AND READ REQUIRED VALUE OF 474 ON SCALE OF $\frac{FC}{B^{2/3}}$

28 APRIL, 1948
R.R. R.H.L.

CHART V

TO DETERMINE V_2^2



EXAMPLE —

GIVEN: $\frac{F_1 C}{B^{2/3}} = 346$

$V_1^2 = 500$

$e^a = 1.103$

REQUIRED:

TO FIND V_2^2

1. DRAW A LINE FROM $\frac{F_1 C}{B^{2/3}} = 346$ TO $V_1^2 = 500$
2. DRAW A VERTICAL LINE FROM $e^a = 1.103$, INTERSECTING THE FIRST LINE AT SOME POINT, X.
3. READ THE REQUIRED VALUE ($V_2^2 = 486$) ON THE RIGHT HAND SCALE.

28 APRIL, 1948
LHL

DISCUSSION OF RESULTS

The following paragraphs discuss the results as found on each individual curve. A comparison of the results will be found in CONCLUSIONS AND RECOMMENDATIONS. Since variations with travel of the several variables were found to be slight, only a few points are necessary to obtain these curves.

Curve I.

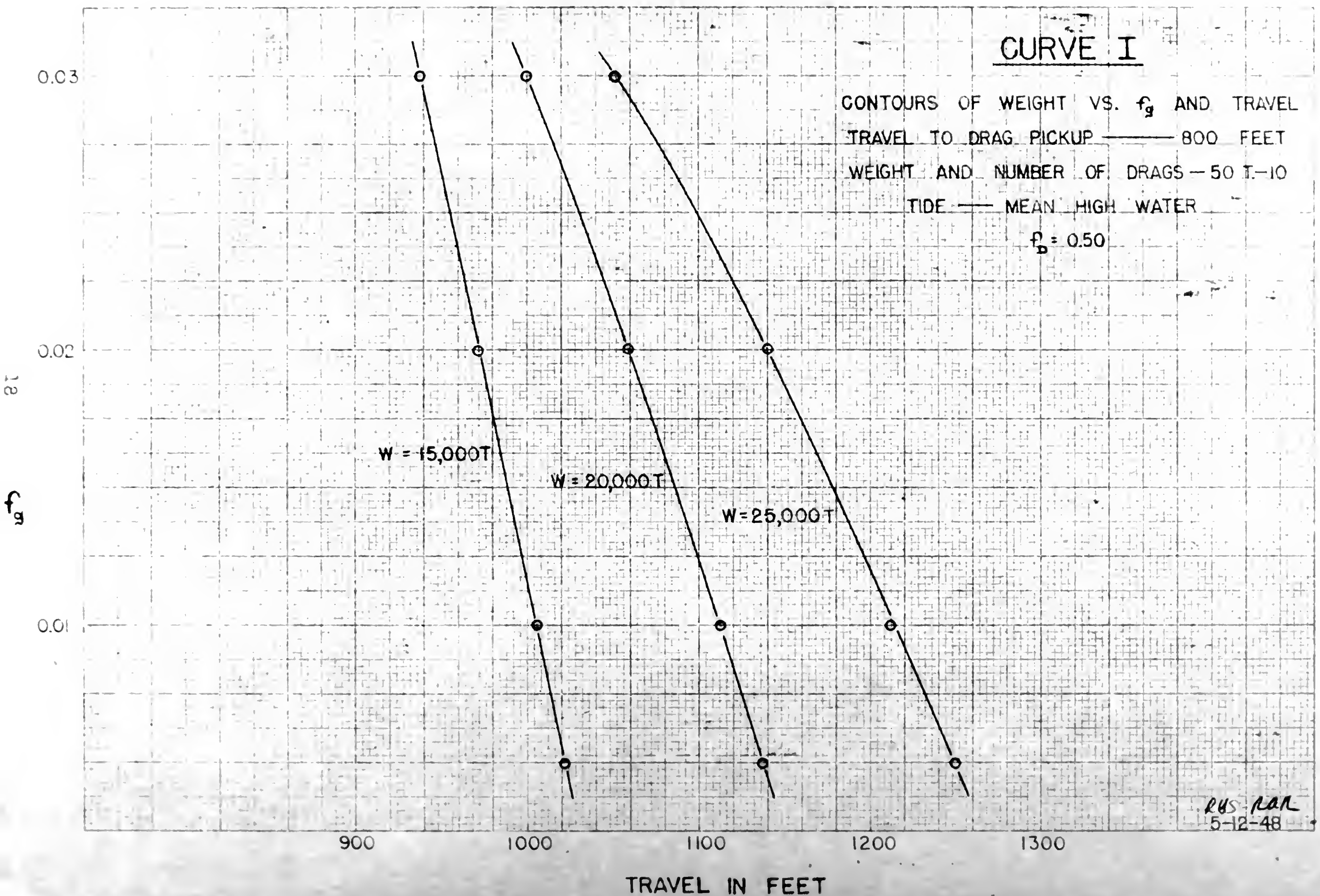
A plot of Ultimate Travel versus Coefficient of Grease Friction for Contours of Constant Weight (ship and cradle), other chart variables being held constant. The following results are noted:

1. The relative effect of the coefficient of grease friction on ultimate travel increases as the weight increases.
2. For any one weight, ultimate travel varies inversely and linearly as the coefficient of grease friction.
3. For any one coefficient of grease friction, ultimate travel is proportional to the weight.

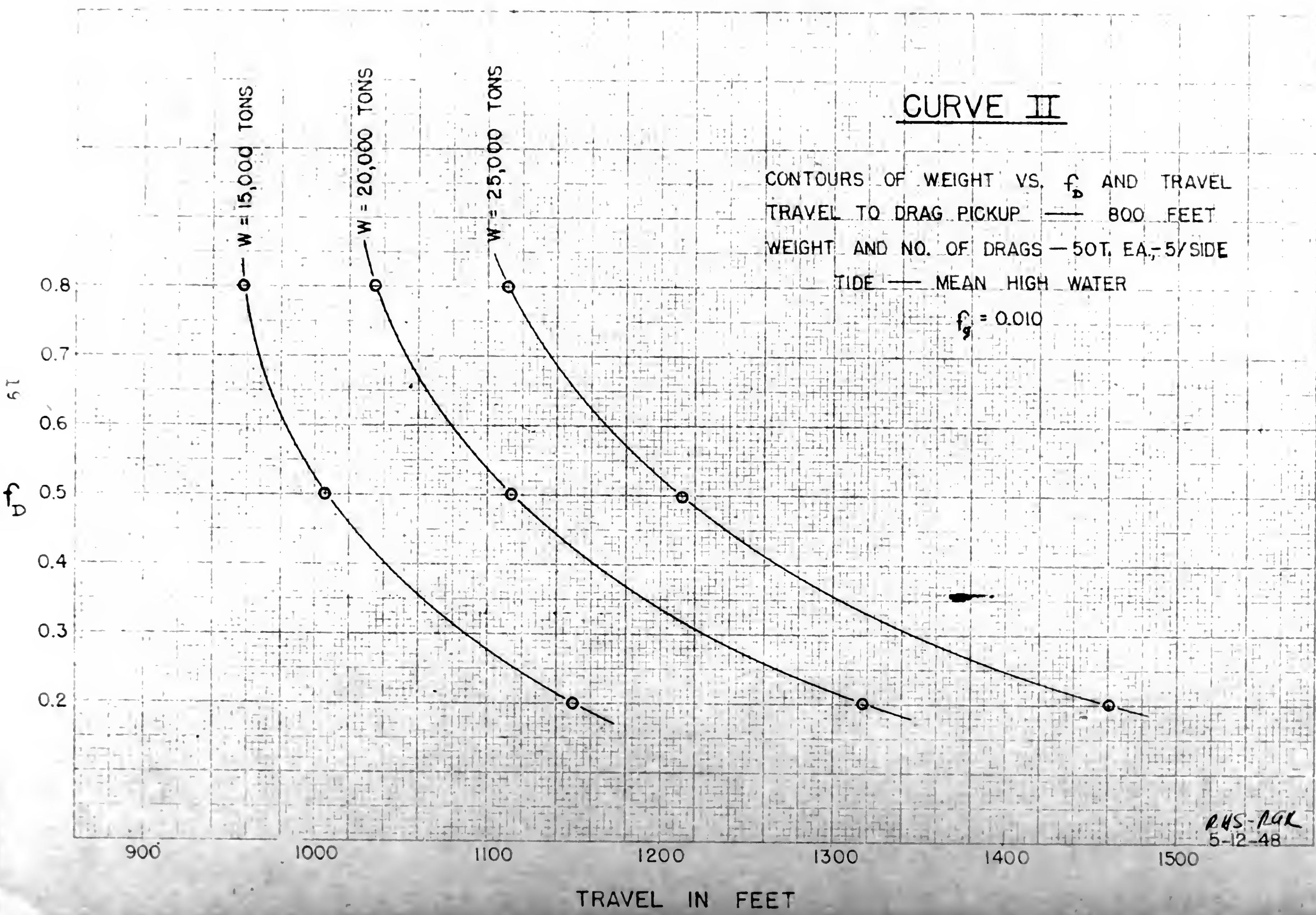
Curve II.

A plot of Ultimate Travel versus Coefficient of Drag Friction for Contours of Constant Weight (ship and cradle), other chart variables being held constant. The following results are noted:

1. The relative effect of the coefficient of drag friction on the ultimate travel increases as the displacement increases.



CURVE I
CONTOURS OF WEIGHT VS. f_g AND TRAVEL
TRAVEL TO DRAG PICKUP —— 800 FEET
WEIGHT AND NUMBER OF DRAGS — 50 T.–10
TIDE —— MEAN HIGH WATER
f_D = 0.50
W = 15,000T
W = 20,000T
W = 25,000T
0.03
0.02
0.01
f_g
900
1000
1100
1200
1300
TRAVEL IN FEET
RHS RAR
5-12-48


CURVE II
CONTOURS OF WEIGHT VS. f_D AND TRAVEL
TRAVEL TO DRAG PICKUP — 800 FEET
WEIGHT AND NO. OF DRAGS — 50T. EA., 5/SIDE
TIDE — MEAN HIGH WATER
f_g = 0.010
W = 15,000 TONS
W = 20,000 TONS
W = 25,000 TONS
f_D
0.8
0.7
0.6
0.5
0.4
0.3
0.2
900
1000
1100
1200
1300
1400
1500
TRAVEL IN FEET
RHS-RGK
5-12-48

2. For any one weight, ultimate travel does not vary inversely as the coefficient of drag friction in a straight line manner; instead it is concave to the right. This is to be expected, since with zero coefficient of drag friction the travel is theoretically infinite.

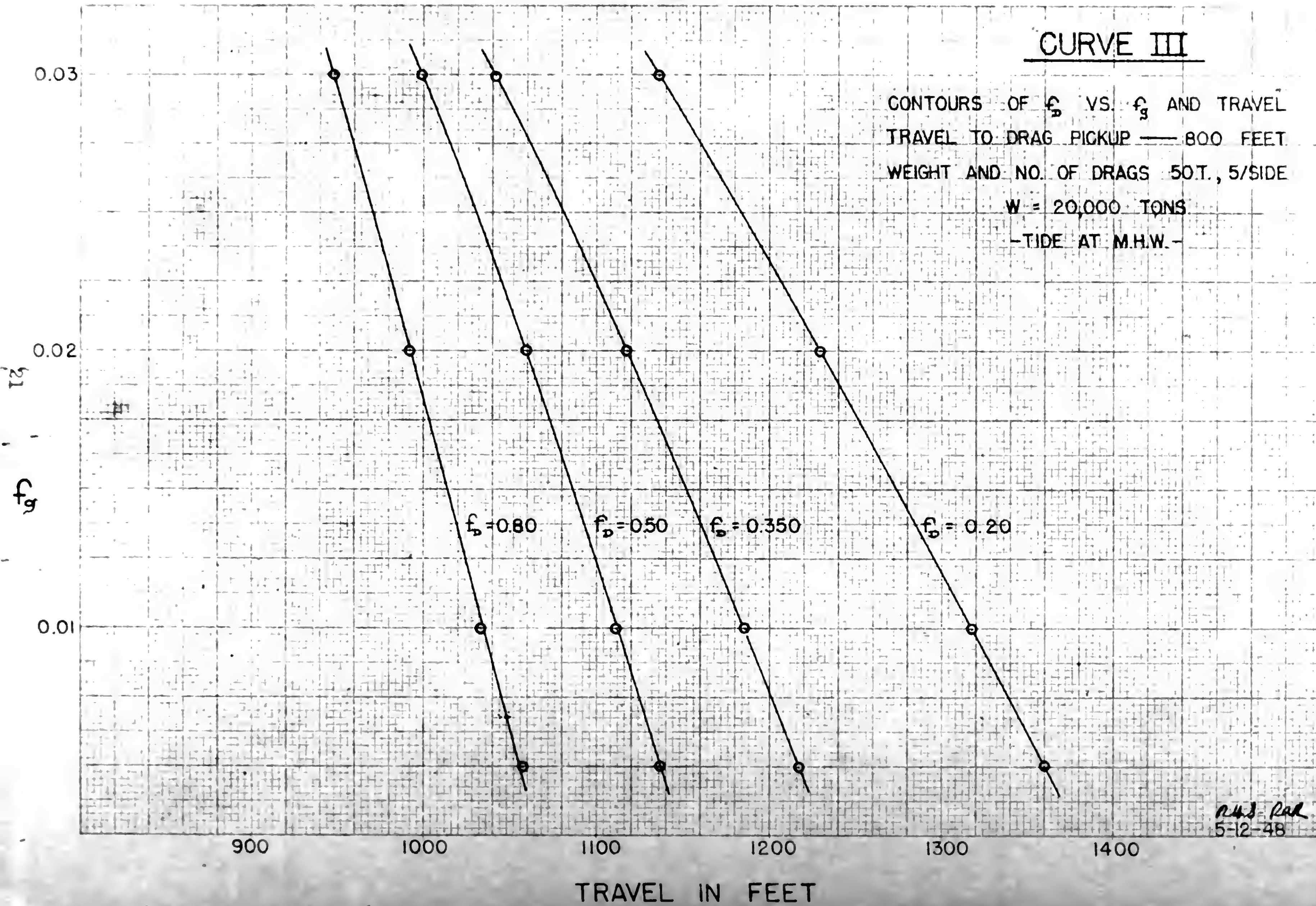
Curve III.

A plot of Ultimate Travel versus Coefficient of Grease Friction for Contours of Constant Drag Friction Coefficient, other chart variables being held constant. The following results are noted:

1. The relative effect of the coefficient of grease friction upon ultimate travel decreases as the coefficient of drag friction increases.
2. For any one coefficient of drag friction, ultimate travel varies inversely and linearly as the coefficient of grease friction.
3. For any one coefficient of grease friction, ultimate travel increases exponentially with a decrease in coefficient of drag friction. For the vessel analyzed by this curve the following relationship was found:-

$$\text{Ultimate travel} \propto f_D^{-1/5}$$

4. The construction of this type of plot which uses extreme expected values of coefficient of grease friction and coefficient of drag friction (other chart variables being



CURVE III
CONTOURS OF f_D VS. f_g AND TRAVEL
TRAVEL TO DRAG PICKUP —— 800 FEET
WEIGHT AND NO. OF DRAGS 50T., 5/SIDE
W = 20,000 TONS
-TIDE AT M.H.W.-
f_D = 0.80
f_D = 0.50
f_D = 0.350
f_D = 0.20
0.03
0.02
0.01
f_g
900
1000
1100
1200
1300
1400
TRAVEL IN FEET
5-12-48

held constant) is very useful since it shows the combination of coefficients for minimum expected travel, maximum expected travel, and all in-between values.

<u>Curve IV.</u>

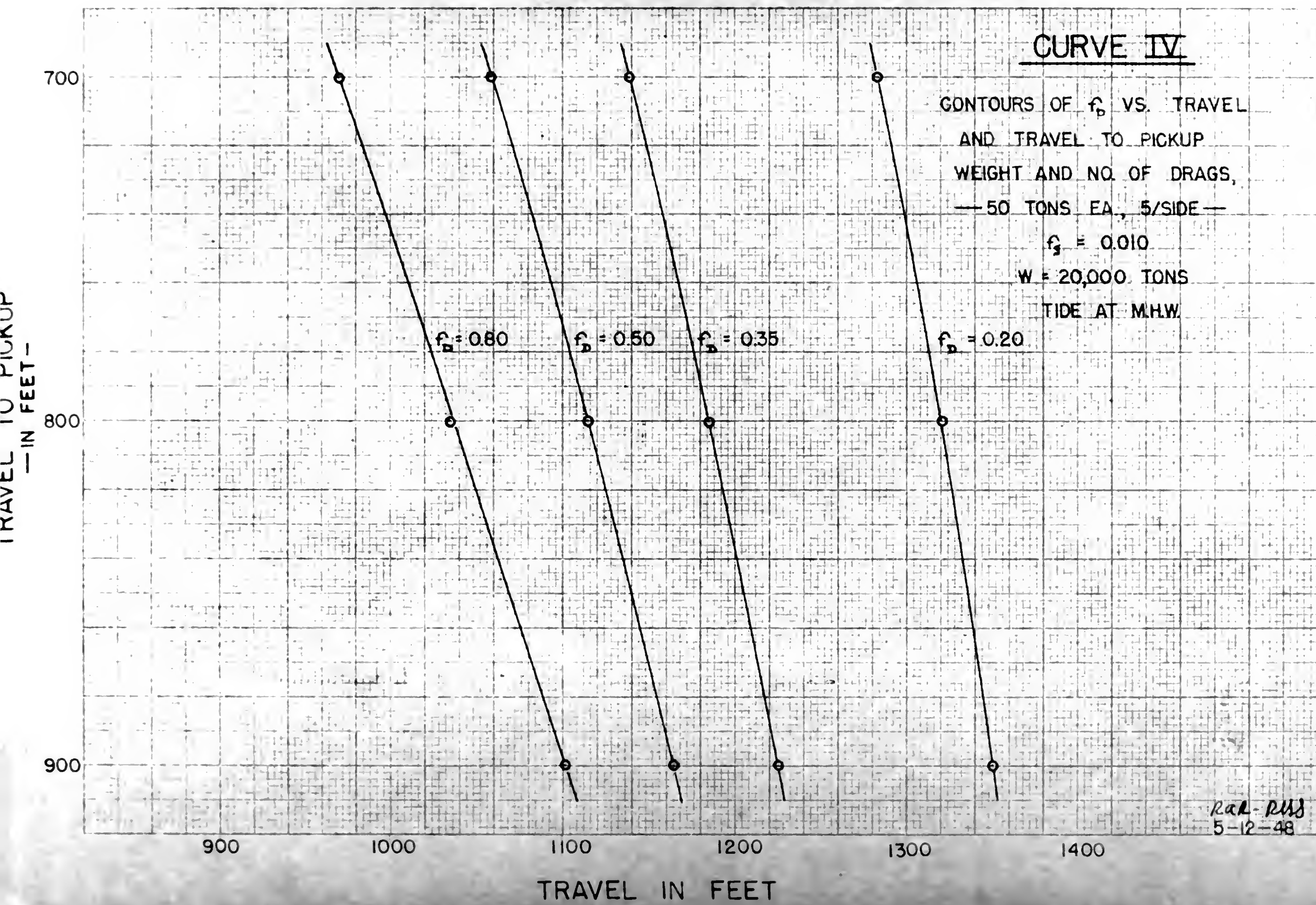
A plot of Point of Pickup of Chain Drags versus Ultimate Travel for Contours of Constant Coefficient of Drag Friction, other chart variables being held constant. The following results are noted:

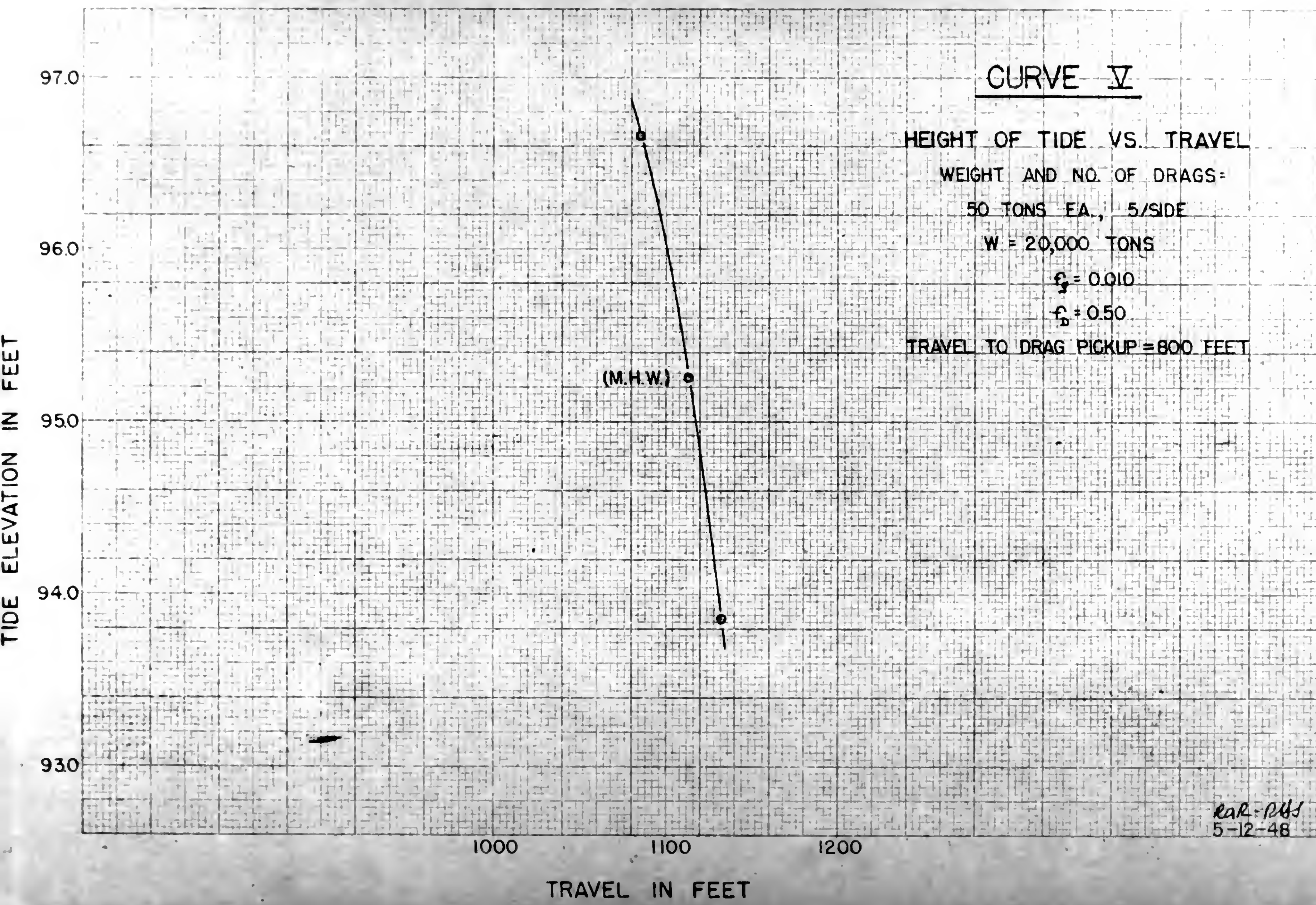
1. The relative effect of a change in the point of pickup upon ultimate travel increases as the coefficient of drag friction increases.
2. For any one coefficient of drag friction, ultimate travel varies linearly with a change in the point of pickup.
3. The increase of ultimate travel is less than the extension of travel to the point of pickup. In one case, where the point of pickup is delayed 60 feet, the ultimate travel of the vessel is only 40 feet greater.

<u>Curve V.</u>

A plot of Height of Tide versus Ultimate Travel of Vessel, all other chart variables being held constant. The following result is noted:

1. The effect of a variation in the height of tide upon ultimate travel is practically negligible. For a tide variation of approximately 3 feet, the variation of


CURVE IV
CONTOURS OF f_D VS. TRAVEL AND TRAVEL TO PICKUP
WEIGHT AND NO. OF DRAGS,
— 50 TONS EA., 5/SIDE —
f_S = 0.010
W = 20,000 TONS
TIDE AT M.H.W.
f_D = 0.80
f_D = 0.50
f_D = 0.35
f_D = 0.20
700
800
900
TRAVEL TO PICKUP — IN FEET —
900
1000
1100
1200
1300
1400
TRAVEL IN FEET
RAL-RUS
5-12-48



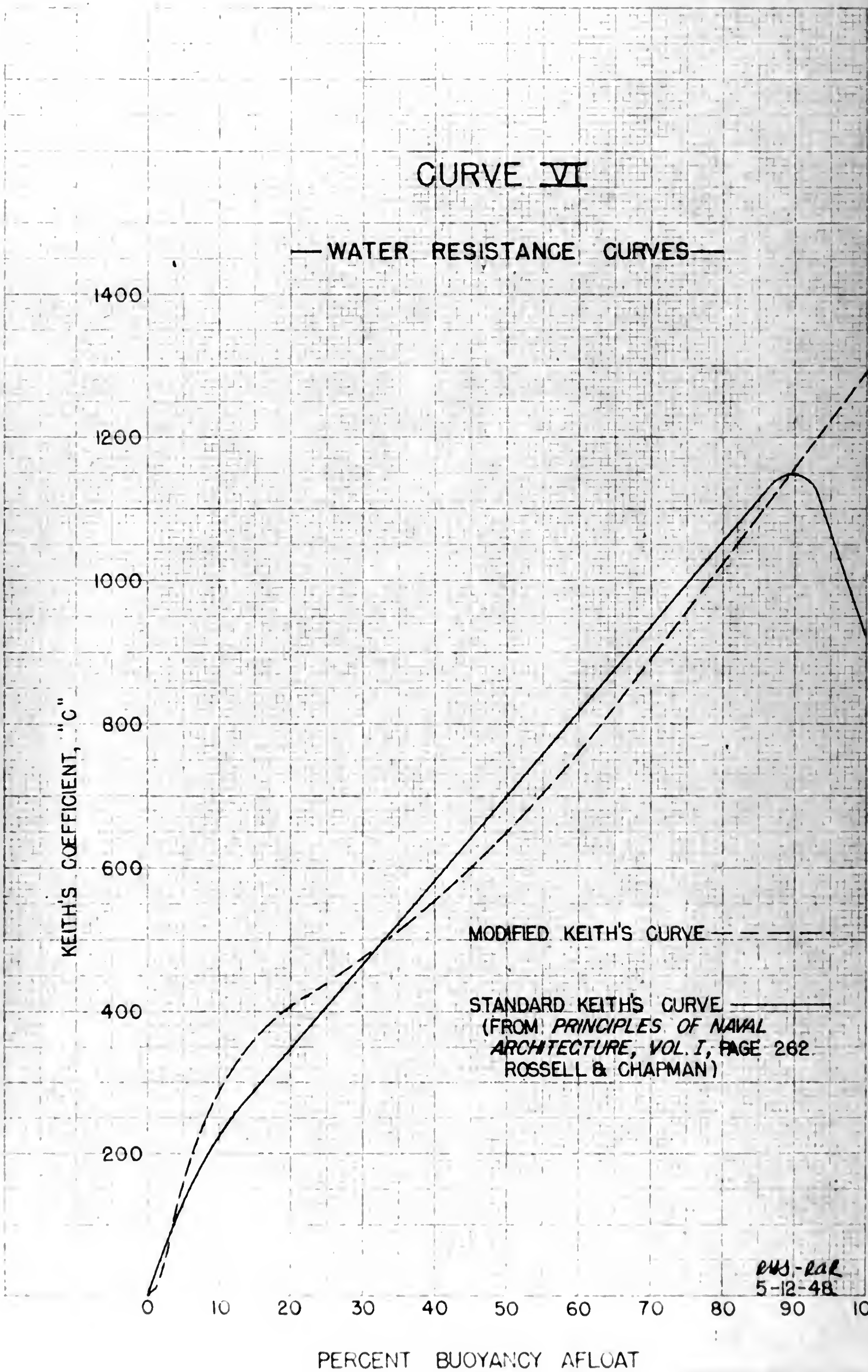
CURVE V
HEIGHT OF TIDE VS. TRAVEL
WEIGHT AND NO. OF DRAGS:
50 TONS EA., 5/SIDE
W = 20,000 TONS
f_s = 0.010
f_D = 0.50
TRAVEL TO DRAG PICKUP = 800 FEET
(M.H.W.)
97.0
96.0
95.0
94.0
93.0
TIDE ELEVATION IN FEET
1000
1100
1200
TRAVEL IN FEET
RAR-RHS
5-12-48

ultimate travel was only 50 feet. It must be realized, however, that the height of tide is a very important factor in determining the way-end pressure produced at launching.

Curve VI.

A plot of the curve of Standard Keith's Coefficient, "C", of Water Resistance versus a Modified Curve of Keith's Coefficient, "C", the area under each curve being kept constant. The authors have assumed that the standard Keith's Curve was constructed from data obtained on ship launchings at which large chain drag forces were present.

In calculating the ultimate travel for a ship utilizing large chain drag forces, (using first the Standard Keith's Curve and then the Modified Keith's Curve, holding all other variables constant), it was found that the use of the Modified Keith's Curve increased the ultimate travel by only some 20 feet. Thus, the "100% Buoyancy Afloat" value of Keith's Coefficient, "C", has relatively little effect upon the calculated point of ultimate travel when large chain drag forces are applied. However, if the drag force is considerably reduced, the vessel will travel a greater distance in a fully waterborne condition and the end value of Keith's Coefficient becomes extremely important inasmuch as it determines almost the total resistance during this interval.


CURVE VI
—WATER RESISTANCE CURVES—
1400
1200
1000
800
600
400
200
KEITH'S COEFFICIENT, "C"
MODIFIED KEITH'S CURVE
STANDARD KEITH'S CURVE
(FROM PRINCIPLES OF NAVAL ARCHITECTURE, VOL. I, PAGE 262. ROSSELL & CHAPMAN)
0
10
20
30
40
50
60
70
80
90
100
PERCENT BUOYANCY AFLOAT
ews-eae
5-12-48

CONCLUSIONS AND RECOMMENDATIONS

The form of the basic equation (2), is that of a recursion formula. That is, to find the ultimate travel, or point at which $V_f^2 = 0$, one cannot simply substitute values into a formula and solve for V_f^2. This is because the several variables come into play at different times during travel, or in other words, the functions of the variables are discontinuous. The step-by-step method lends itself to determination of V_f^2 for increments of travel over which these functions are continuous, thus giving a curve of velocities which, when plotted against travel, is a close approximation to the actual velocity curve. With these circumstances in mind, the nomograms developed in this thesis report greatly reduce the steps required to find the points on the velocity curve. For the same reason that no one formula will yield the ultimate travel, no one nomogram will.

From a comparison of Curves I through VI, the following conclusions are drawn:

1. The net chain drag force is the most important variable affecting the ultimate travel of a vessel at launching.
2. The resultant increase in ultimate travel caused by a delay in the point of pickup of chain drags is less than the delay in point of pickup.
3. A moderate variation in the height of tide has very little

effect upon ultimate travel of a vessel at launching.

4. A variation in the coefficient of grease friction has little effect upon the ultimate travel of a vessel at launching. Thus, the atmospheric temperature on the day of launching, which affects the coefficient of grease friction, need not be an important consideration.

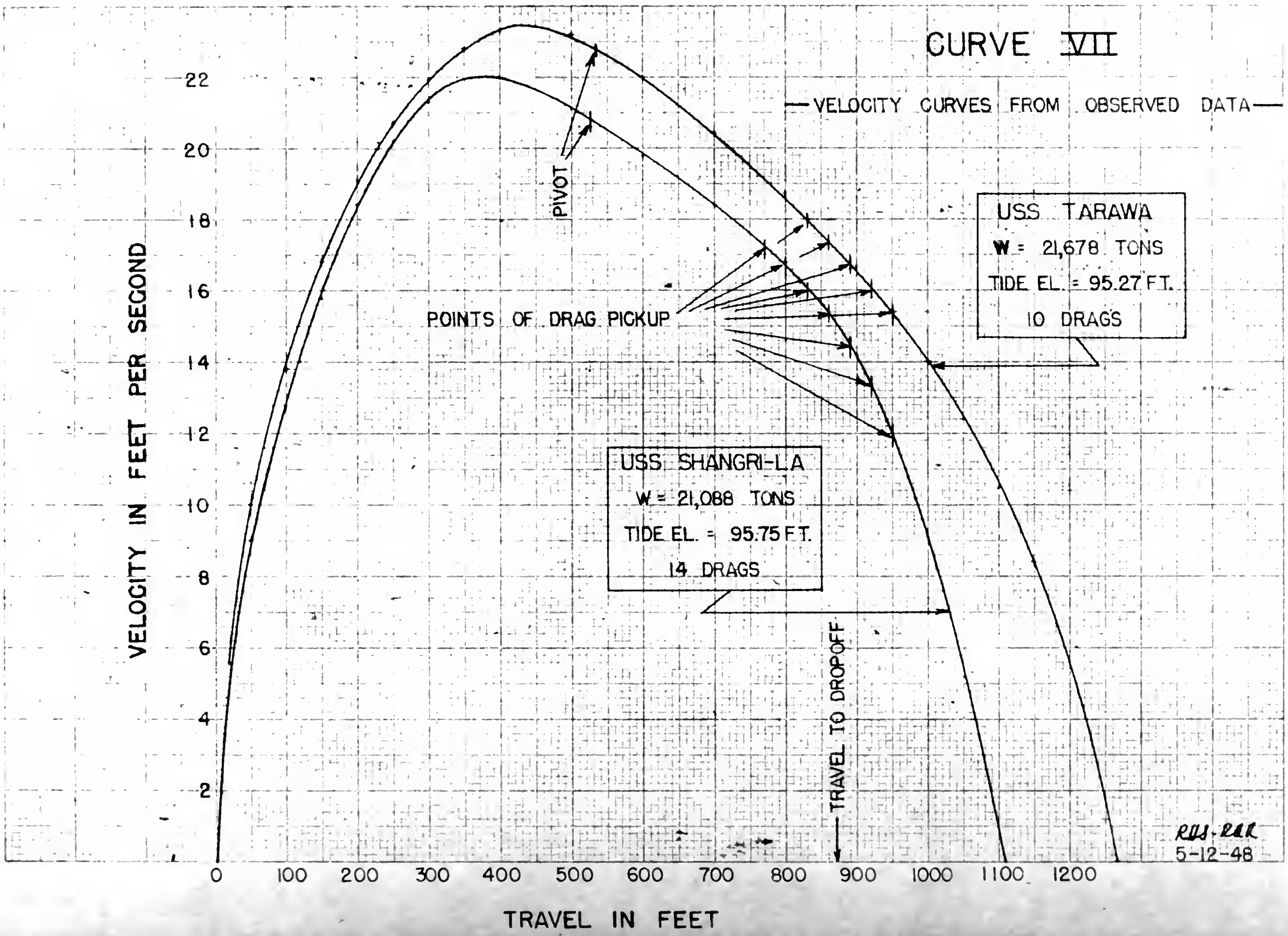
5. A moderate change in the combined weight of the vessel and its cradle has little effect upon ultimate travel.

6. The value of Keith's Coefficient, "C", of Water Resistance when the vessel is completely waterborne becomes increasingly important in determining the point of ultimate travel as the interval of completely waterborne travel increases.

The nomographic charts developed herein present a rapid means of obtaining the point of ultimate travel at launching when use is made of the force equation outlined in the PROCEDURE. These charts will yield an answer in about one-fourth of the time required by the conventional methods of step-by-step calculations with far less likelihood of error, since less computation is required. It must be understood that the accuracy of the end point result obtained is no greater than that of the assumed coefficients. Also, these nomographic charts furnish a more accurate means of calculating than an ordinary ten-inch slide rule.

All numerical results contained in this thesis are based on calculations using the Standard Curve of Keith's Coefficient, "C", of Water Resistance as found on Chart I. In the event that a modified form of Keith's Curve is to be used it may be substituted for the Standard Keith's Curve on Chart I and the same nomographic method applied to obtain the desired point of ultimate travel.

A further investigation seems warranted to determine the accuracy of the end point value (fully waterborne condition) of Keith's Coefficient, "C", of Water Resistance. From recent launching data (USS SHANGRI-LA, CV-38), the end point value of "C" appears to be about 1400. This was computed from data obtained with a gyro-accelerometer mounted on board the vessel at the time of launching. The velocity curve derived from this accelerometer is shown in Curve VII.


CURVE VII
VELOCITY CURVES FROM OBSERVED DATA
USS TARAWA
W = 21,678 TONS
TIDE EL. = 95.27 F.T.
10 DRAGS
USS SHANGRI-LA
W = 21,088 TONS
TIDE EL. = 95.75 F.T.
14 DRAGS
PIVOT
POINTS OF DRAG PICKUP
TRAVEL TO DROPOFF
VELOCITY IN FEET PER SECOND
TRAVEL IN FEET
0 100 200 300 400 500 600 700 800 900 1000 1100 1200
2 4 6 8 10 12 14 16 18 20 22
RUS-RAR
5-12-48

APPENDIX

General Equations

To determine the velocity of a vessel at any point of its Travel, a step-by-step method of calculation must be used. The step taken is from a known velocity to the point of travel where the desired velocity obtains. A maximum of fifty feet per step or increment of travel, is used in this thesis.

At least two types of equations for the determination of the ultimate travel of a ship upon launching are used in present day practice, the force equation and the energy equation.

This thesis considers only the force equation, which states that the resultant force acting on the ship in its line of motion equals the mass of ship and cradle times its acceleration.

The following symbols are used:

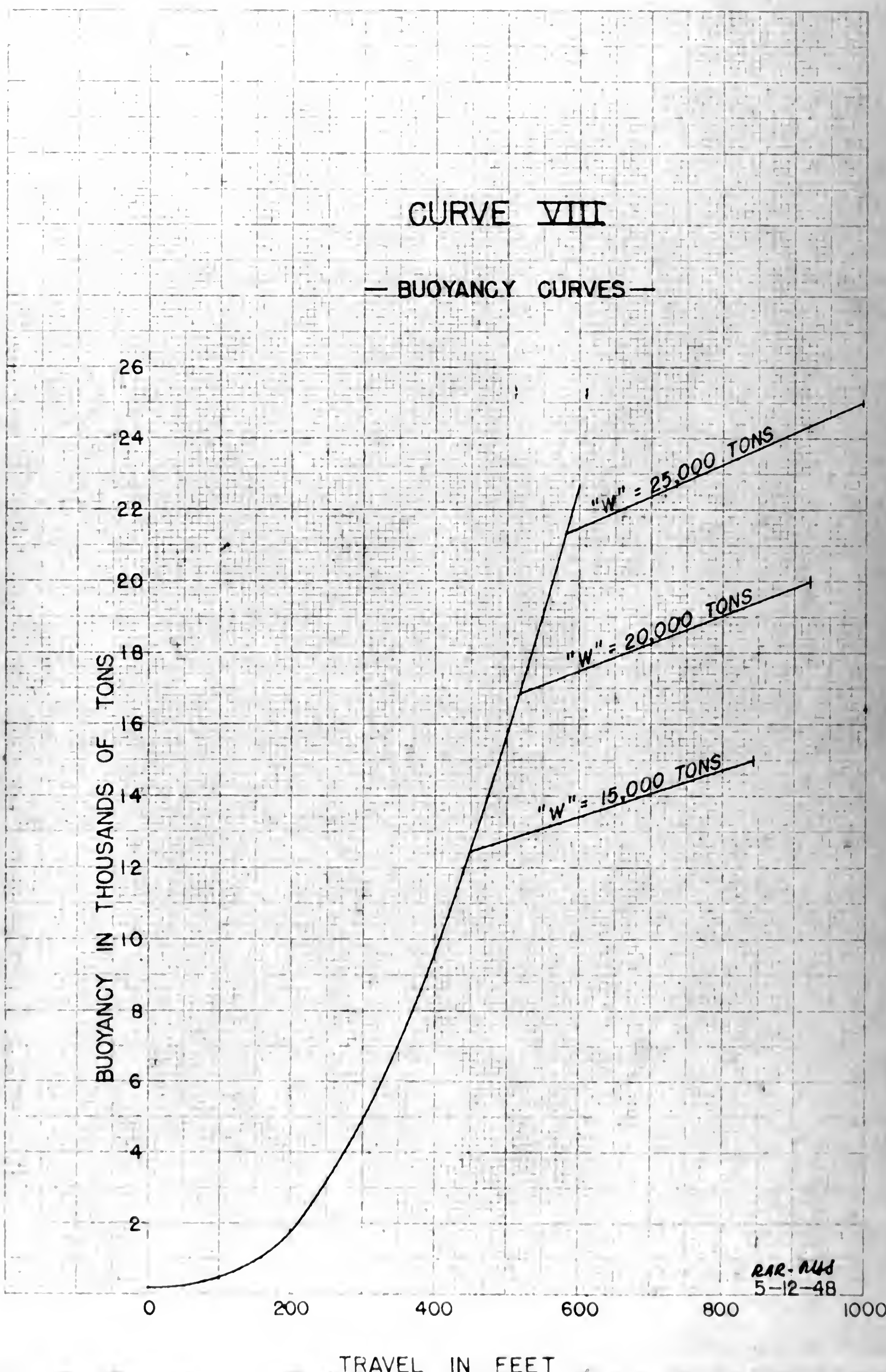
W = Weight of ship and cradle, in tons

B = Average buoyancy of ship, in tons, over increment of travel, read from Chart VIII, (Cradle is assumed self buoyant)

θ = Angle of declivity of ways

a = Acceleration of ship in line of travel

F_1 = Average downways component of ship's weight minus the average upways components of:


CURVE VIII
— BUOYANCY CURVES —
BUOYANCY IN THOUSANDS OF TONS
26
24
22
20
18
16
14
12
10
8
6
4
2
"W" = 25,000 TONS
"W" = 20,000 TONS
"W" = 15,000 TONS
RAR-NHS
5-12-48
0
200
400
600
800
1000
TRAVEL IN FEET

1. Buoyancy

2. Grease friction

3. Chain drag resistance

g = Gravitational constant

S_1 = Distance ship travels to beginning of any increment

S_2 = Distance ship travels to end of any increment

S' = Distance ship travels beyond last increment for V_2^2 positive

$S = S_2 - S_1$

V_1 = Velocity at point of travel, S_1

V_2 = Velocity at point of travel, S_2

V_f = Velocity at end of any increment in general

D = Weight of chain drags in action

f_g = Coefficient of grease friction

f_d = Coefficient of chain drag friction (or resistance)

K = Constant of proportionality between water resistance in tons and ship's speed, V^2, in $(\text{ft./sec.})^2$

$= \dfrac{B^{2/3}}{C}$

C = Keith's Coefficient of water resistance

The derivation of the equation for velocity at the end of any increment of travel follows:

From fundamental mechanics

$$F_{NET} = \text{MASS} \times \text{ACCELERATION}$$

$$F_{NET} = \frac{Wa}{g}$$

$$\frac{gF_{NET}}{W} = a = \frac{dv}{dt} = \frac{dv}{ds} \cdot \frac{ds}{dt} = V\frac{dv}{ds}$$

So, $$\frac{gF_{NET}}{W} = V\frac{dV}{ds} \qquad (5)$$

Let us assume that the drag force and grease friction act in the direction of the line of motion of the vessel. Then the total force causing acceleration is:

$$F_1 - KV^2 = F_{NET} \qquad (6)$$

where KV^2 is the resistance of the water and K is determined from Keith's Curve of Water Resistance Coefficients.

Therefore, $$\frac{g}{W}(F_1 - KV^2) = V\frac{dv}{ds} \qquad (7)$$

Note that average values of F_1 and K over the increment are to be used, so that the forces may be considered as constants for the entire increment in question.

Separating the variables in Equation (7), we obtain:

$$\frac{g\,ds}{W} = \frac{V\,dV}{F_1 - KV^2} \tag{8}$$

and integrating both sides between limits;

$$\frac{g}{W}\int_{S_1}^{S_2} ds = \frac{1}{-2K}\int_{V_1}^{V_2} \frac{(-2K)V\,dV}{F_1 - KV^2} \tag{9}$$

$$\frac{-2gK}{W}(S_2 - S_1) = \Big[\log_e (F_1 - KV^2)\Big]_{V_1}^{V_2} \tag{10}$$

$$\frac{-2gK}{W}(S_2 - S_1) = \log_e \left\{\frac{F_1 - KV_2^2}{F_1 - KV_1^2}\right\} \tag{11}$$

Taking antilog of both sides of Equation (11),

$$e^{\frac{-2gK}{W}(S_2 - S_1)} = \frac{F_1 - KV_2^2}{F_1 - KV_1^2} \tag{12}$$

$$(F_1 - KV_1^2)\, e^{\frac{-2gK}{W}(S_2 - S_1)} = F_1 - KV_2^2 \tag{13}$$

$$\frac{F_1}{K} - \frac{(F_1 - KV_1^2)}{K}\, e^{\frac{-2gK}{W}(S_2 - S_1)} = V_2^2 \tag{14}$$

Equation (14), after putting $K = \frac{B^{2/3}}{C}$, reduces to:

$$V_2^2 = \frac{1}{e^{\frac{2gK}{W}(S_2-S_1)}}\left[V_1^2 + \frac{CF_1\left(e^{\frac{2gK}{W}(S_2-S_1)}-1\right)}{B^{2/3}}\right] \qquad (15)$$

Where $F_1 = (W-B)\sin\theta - (W-B)f_g\cos\theta - Df_d$

The foregoing expression is further simplified by saying that, since θ is quite small,

$\sin\theta = \theta$, in radians

$\cos\theta = 1.00$

Therefore, $F_1 = (W-B)(\theta - f_g) - Df_d$ (16)

One of the objectives of this thesis is to develop a rapid method of finding the end point of travel (at which $V_2^2 = 0$), based on assumed values of retarding variables. The method developed is discussed in the next section.

Development of Nomographic Charts.

CHART I is a Z-type nomogram used to determine the percent buoyancy afloat. Keith's curve is drawn as given in Principles of Naval Architecture, Vol. I., Page 262, with the Z-type chart below it. "B" is read from Curve VIII and averaged over the increment. In Fig. (1), it can be seen by similar triangle analysis,

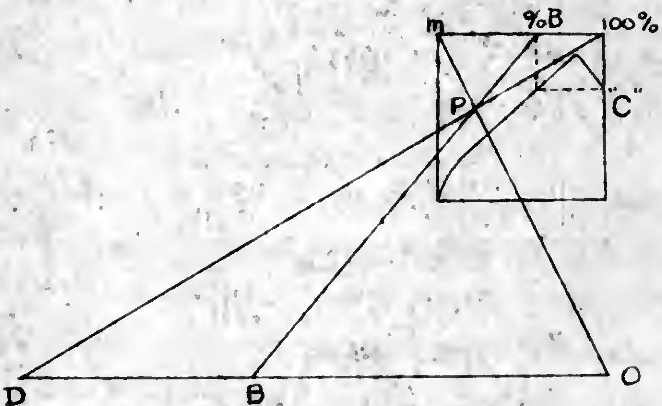


Figure I

Since $$\frac{\overline{OB}}{\%B} = \frac{\overline{OP}}{\overline{mP}} \tag{17}$$

and $$\frac{\overline{OD}}{100\%(B)} = \frac{\overline{OD}}{1} = \frac{\overline{OP}}{\overline{mP}} \tag{18}$$

therefore $$\%B = \frac{\overline{OB}}{\overline{OD}} \tag{19}$$

Therefore, the value of "%B Afloat" is correct as read. "C" is read as from a normal graph by noting the intersection of the absissca of "%B Afloat" and the "C" curve.

CHART II is a nomogram to determine values of e^Q, based on equation:

$$e^Q = e^{\frac{2B^{2/3} g S}{WC}} \qquad (S = S_2 - S_1) \qquad (20)$$

Taking $\log_{10}$ of both sides, twice,

$$\log_{10} e^Q = \frac{2B^{2/3} g S}{WC} \cdot \log_{10} e \qquad (21)$$

$$\log_{10} \log_{10} e^Q = \frac{2}{3} \log_{10} B + \log_{10} 2g + \log_{10} S - \log_{10} W - \log_{10} C + \log_{10} \log_{10} e \qquad (22)$$

$$\frac{2}{3} \log_{10} B - \log_{10} \log_{10} e^Q = \log_{10} W + \log_{10} C - \log_{10} (2gS \log_{10} e) \qquad (23)$$

This gives the form of Chart II, which can be proved by congruent triangles if the index line is midway between the scales for "C" and "B".

To simplify the chart design, lay off values of $\frac{2}{3}\log_{10} B$ as a B scale, and values of $\log_{10} \log_{10} e^Q$ as an e^Q scale on the same line. Draw a "C" scale as on Chart II, using values of $\log_{10} C$ with the index line midway between the "C"- and "B"-scales, as shown. Then, calculate e^Q for any reasonable values of "W", "C", and "B". If a value of "W" = 1000 is used, the process of laying out the "W"-scale is simplified. Draw a line between the points of "C" and e^Q, crossing the index line at some point X. A line from the chosen value of "B" through X determines "W" on a line of the "C"-scale extended. From this point, and to the same scale as "C", lay off values of $\log_{10} W$ using standard $\log_{10}$ tables. A second similar calculation with the assumed value of "W" greater than the first will determine the direction of the "W"-scale.

Note that "B" is always less than or equal to "W" for any given ship.

CHART III is a nomogram to determine the downways force, F_1, and is a pair of Z-charts with a difference scale superimposed.

It is desired to solve the following equation:

$$F_1 = (W-B)\theta - f_g(W-B) - f_d D \qquad (24)$$

$$F_1 = (\theta - f_g)(W-B) - f_d D \qquad (25)$$

The Z chart is constructed as follows:

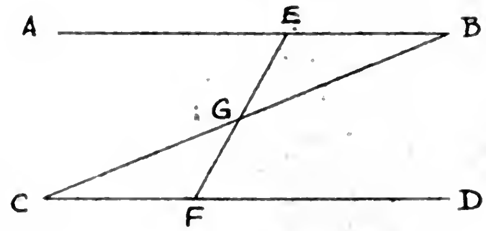


Figure II

Draw two parallel lines $\overline{AB}$ and $\overline{CD}$, and draw $\overline{BC}$. Connect E and F from any points on $\overline{AB}$ and $\overline{CD}$, intersecting $\overline{BC}$ in some point G.

Since triangles EBG and CGF are similar, $\overline{EB}$ = const x $\overline{CF}$. This is the form desired to solve Equation (25).

To lay out the chart for the first term of the right hand side of Equation (25), mark divisions to some convenient scale of (W-B) on $\overline{BA}$. To any convenient scale on $\overline{CD}$, lay out values for $(\theta - f_g)(W-B)$. Then, with any convenient values of $(\theta - f_g)$ and (W-B), calculate the product $(\theta - f_g)(W-B)$. Mark this point on its scale. Draw $\overline{EF}$, labeling the point G, (on the line connecting the zero points of the (W-B)- and $(\theta - f_g)(W-B)$-scales), with the value of f_g used in the calculation. Point G will thus be the pivot point for all values of (W-B) and the assumed value of f_g with a slope of ways equal to θ. Pivot points for other

values of f_g are calculated similarly.

CHART III is designed for slope of 9-16", but pivot points on the f_g scale for other declivities can be readily located by the method just described. Scales similar to those for (W-B), f_g, and $(\theta - f_g)(W-B)$ are laid off on CD, CB, and BA for weight of drags, D, drag coefficient of resistance, f_d, and drag force Df_d.

Midway between $\overline{AB}$ and $\overline{CD}$, a parallel line is drawn on which is drawn a scale of differences between the scales of $(\theta - f_g)(W-B)$ and Df_d. Each of these points is located by taking any convenient values of $(\theta - f_g)(W-B)$ and Df_d, subtracting them, drawing a line between them cutting the difference scale line at a point, and labeling the point with the computed difference. Thus, the scale of the difference line is at once determined.

CHART IV is a nomogram used to determine $\frac{F_1 C}{B^{2/3}}$. Taking the $\log_{10}$ of this, we have:

$$\log_{10} \frac{F_1 C}{B^{2/3}} = \log_{10} F_1 + \log_{10} C - \frac{2}{3} \log_{10} B \qquad (26)$$

$$\log_{10} F_1 - \log_{10} \frac{F_1 C}{B^{2/3}} = \frac{2}{3} \log_{10} B - \log_{10} C \qquad (27)$$

To construct the chart, draw three parallel equidistant lines $\overline{AB}$, $\overline{CD}$, $\overline{EF}$.

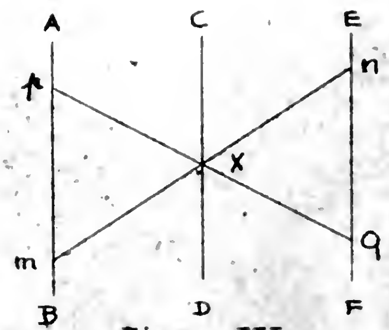


Figure III

Draw $\overline{mn}$ and $\overline{pq}$, causing them to intersect at some point X, on $\overline{CD}$. From any reference point below m and q, lay off a $\log_{10}$ scale on $\overline{BA}$ and on $\overline{FE}$. Because of the congruent triangles pXm and nXq, pm = nq. If n is laid off as $\frac{2}{3}\log_{10} B$, q as $\log_{10} C$, p as $\log_{10} F_1$, then m will lie on the value of $\frac{F_1 C}{B^{2/3}}$. Due to ambiguities of sign and construction, Chart IV must be used in the following order:

1. Draw a line from F_1 to C.
2. Draw a line from B through X to locate $\frac{F_1 C}{B^{2/3}}$.

Note, the algebraic sign of $\frac{F_1 C}{B^{2/3}}$ is the same as that of F_1.

CHART V is a nomogram to determine V_2^2 and is designed in a different manner from the others. This chart is used to solve the final equation whose component parts are determined by Charts I through IV.

The equation is:

$$V_2^{\,2}\, e^{Q} - V_1^{\,2} = M(e^{Q} - 1) \tag{28}$$

Where $M = \frac{F_1 C}{B^{2/3}}$

Let $x = V_2^{\,2}$

$y = M$

Writing parametric equations, we have:

$$\begin{aligned} e^{Q} x - y(e^{Q} - 1) &= V_1^{\,2} \\ x \qquad\qquad &= V_2^{\,2} \\ y &= M \end{aligned} \tag{29}$$

The determinant of this may be written:

$$\begin{vmatrix} e^{Q} & -(e^{Q}-1) & V_1^{\,2} \\ 1 & 0 & V_2^{\,2} \\ 0 & 1 & M \end{vmatrix} = \begin{vmatrix} e^{Q} & 1 & V_1^{\,2} \\ 1 & 1 & V_2^{\,2} \\ 0 & 1 & M \end{vmatrix} = \begin{vmatrix} 1 & V_1^{\,2} & 1 \\ \frac{1}{e^{Q}} & V_2^{\,2} & 1 \\ 0 & M & 1 \end{vmatrix} = 0 \tag{30}$$

But this is the equation of a straight line laid out on x-y axes. When $x = 1$, $y = V_1^{\,2}$; when $x = \frac{1}{e^{Q}}$, $y = V_2^{\,2}$; when $x = 0$, $y = M$. A perusal of Chart V will disclose the method of plotting.

The scale of $\frac{F_1C}{B^{2/3}}$ is the y-axis, and although the scale of $\frac{1}{e^{Q}}$ is plotted on the x-axis; the label for each point is "e^{Q}".

Typical examples are shown in Tables I and II. Table I is computed with aid of the charts, while Table II is computed with sliderule and calculating machine. The former table required one hour to fill in; the latter, about four hours. The chance of error in using Table I with the charts is negligibly small compared to the calculating machine method. The difference in the answers obtained by the two methods is quite negligible, being only four feet in 1100 feet for the example as shown in Tables I and II.

TABLE I

Nomographic Chart Method

For Determination of Ultimate Travel

Travel	S	B (Avg.)	C	e^Q	W-B	F_1	$\frac{F_1 C}{B^{2/3}}$	$V_2^{\,2}$	V_2
0-50	50	200	28	1.22	19,800	730	598	108	10.4
50-100	50	325	47	1.18	19,675	726	722	201	14.2
100-150	50	650	86	1.15	19,350	714	820	281	16.8
150-200	50	1300	160	1.128	18,700	690	920	352	18.8
200-250	50	2500	260	1.123	17,500	646	910	415	20.4
250-300	50	4100	355	1.121	15,900	587	805	458	21.4
300-350	50	6100	475	1.120	13,900	514	730	486	22.0
350-400	50	8400	610	1.115	11,600	428	640	501	22.4
400-450	50	11200	772	1.110	8,800	325	500	500	22.4
450-500	50	14200	945	1.103	5,800	215	346	486	22.0
500-510	10	16200	1065	1.02	3,800	141	235	480	21.9
510-550	40	16900	1105	1.081	3,100	116	194	458	21.4
550-600	50	17300	1135	1.096	2,700	100	168	432	20.8
600-650	50	17700	1148	1.101	2,300	86	143	405	20.1
650-700	50	18050	1150	1.100	1,950	73	122	380	19.5
700-750	50	18450	1135	1.103	1,550	58	95	352	18.8
750-800	50	18850	1085	1.110	1,150	43	65	325	18.0
800-830	30	19100	1055	1.071	900	-15	-21	300	17.3
830-860	30	19400	1000	1.076	600	-79	-110	271	16.5
860-890	30	19600	980	1.078	400	-135	-183	238	15.4
890-920	30	19850	945	1.080	150	-193	-246	201	14.2
920-950	30	20000	910	1.083	0	-250	-310	161	12.7
950-1000	50	20000	910	1.138	0	-250	-310	105	10.2
1000-1050	50	20000	910	1.138	0	-250	-310	55	7.4
1050-1100	50	20000	910	1.138	0	-250	-310	10	3.2
1100-1150	50	20000	910	1.138	0	-250	-310	-29	-
1150-1200	50	20000	910	1.138	0	-250	-310	-29	-

W = 20,000 Tons
10 Drags - 50 Tons each
$f_g = 0.010$
$f_d = 0.500$

Total Travel = 1113 Feet

TABLE II

Calculating Machine and Slide Rule Method

For Determination of Ultimate Travel

Increment No.	(1) Travel	(2) S (Increment)	(3) B Buoyancy (Average)	(4) (W-B)	(5) (W-B) x sin θ	(6) f_g(W-B)	(7) Drag Force
1	0-50	50	200	19,800	927	198	0
2	50-100	50	325	19,675	921.2	196.8	0
3	100-150	50	650	19,350	906	193.5	0
4	150-200	50	1,300	18,700	875.5	187	0
5	200-250	50	2,500	17,500	819.3	175	0
6	250-300	50	4,100	15,900	744.4	159	0
7	300-350	50	6,100	13,900	650.8	139	0
8	350-400	50	8,400	11,600	543.1	116	0
9	400-450	50	11,200	8,800	412	88	0
10	450-500	50	14,200	5,800	271.6	58	0
11	500-510	10	16,200	3,800	177.9	38	0
12	510-550	40	16,900	3,100	145.1	31	0
13	550-600	50	17,300	2,700	126.4	27	0
14	600-650	50	17,700	2,300	107.7	23	0
15	650-700	50	18,050	1,950	91.3	19.5	0
16	700-750	50	18,450	1,550	72.6	15.5	0
17	750-800	50	18,850	1,150	53.8	11.5	0
18	800-830	30	19,100	900	42.1	9	50
19	830-860	30	19,400	600	28.1	6	100
20	860-890	30	19,600	400	18.7	4	150
21	890-920	30	19,850	150	7.0	1.5	200
22	920-950	30	20,000	0	0	0	250
23	950-1000	50	20,000	0	0	0	250
24	1000-1050	50	20,000	0	0	0	250
25	1050-1100	50	20,000	0	0	0	250
26	1100-1150	50	20,000	0	0	0	250
27	1150-1200	50	20,000	0	0	0	250

TABLE II, CONT'D.

Calculating Machine and Slide Rule Method

For Determination of Ultimate Travel

Increment No.	(8) F_1 Net Force	(9) %B Afloat	(10) $B^{2/3}$	(11) C Keith's Coeff.	(12) $\frac{B^{2/3}}{C}$	(13) $Q = \frac{2B^{2/3}gS}{WC}$	(14) e^Q	(15) $\frac{1}{e^Q}$
1	729	1	34.2	28	1.221	0.1964	1.218	0.821
2	724.4	1.63	47.2	47	1.003	0.1615	1.175	0.850
3	712.5	3.25	75	86	0.872	0.1405	1.150	0.870
4	688.5	7.5	119	160	0.744	0.1198	1.127	0.887
5	644.3	12.5	185	260	0.712	0.1146	1.121	0.892
6	585.4	20.5	258	355	0.727	0.1170	1.124	0.890
7	511.8	30.5	332	475	0.699	0.1125	1.128	0.887
8	427.1	42	412	610	0.675	0.1087	1.115	0.897
9	324	56	500	772	0.648	0.1043	1.110	0.901
10	213.6	71	585	945	0.619	0.0997	1.105	0.905
11	139.9	81	640	1065	0.601	0.0194	1.020	0.981
12	114.1	84.5	660	1105	0.597	0.0769	1.080	0.926
13	99.4	86.5	675	1135	0.595	0.0958	1.101	0.909
14	84.7	88.5	685	1148	0.597	0.0961	1.101	0.908
15	71.8	90.3	690	1150	0.600	0.0966	1.102	0.908
16	57.1	92.3	700	1135	0.617	0.0993	1.105	0.905
17	42.3	94.3	705	1085	0.650	0.1047	1.110	0.901
18	-16.9	95.5	710	1055	0.673	0.0650	1.067	0.937
19	-77.9	97	720	1000	0.720	0.0696	1.072	0.933
20	-135.3	98	730	980	0.745	0.0720	1.075	0.930
21	-194.7	99.3	735	945	0.778	0.0752	1.078	0.928
22	-250	100	740	910	0.813	0.0785	1.082	0.924
23	-250	100	740	910	0.813	0.1309	1.140	0.877
24	-250	100	740	910	0.813	0.1309	1.140	0.877
25	-250	100	740	910	0.813	0.1309	1.140	0.877
26	-250	100	740	910	0.813	0.1309	1.140	0.877
27	-250	100	740	910	0.813	0.1309	1.140	0.877

TABLE. II, CONT'D

Calculating Machine and Slide Rule Method

For Determination of Ultimate Travel

Increment No.	(16) $e^q - 1$	(17) $\frac{C}{B^{2/3}}$	(18) $\frac{CF_1}{B^{2/3}}$	(19) $\frac{CF_1(e^q-1)}{B^{2/3}}$	(20) $V_1^2 + \frac{CF_1(e^q-1)}{B^{2/3}}$ (21) From Line Above + (19)	(21) $V_2^2 = \frac{1}{e^q}\left[V_1^2 + \frac{CF_1(e^q-1)}{B^{2/3}}\right]$	(22) V_2
1	.218	.819	597	130.1	130.1	106.8	10.3
2	.175	.998	720	126	232.8	197.9	14.1
3	.150	1.147	817	122.6	320.5	279	16.7
4	.127	1.343	925	117.5	396.5	351.7	18.8
5	.121	1.405	905	109.5	461.2	411.4	20.3
6	.124	1.375	805	99.8	511.2	455	21.3
7	.128	1.430	732	93.7	548.7	486.7	22.1
8	.115	1.482	633	72.8	559.5	501.9	22.4
9	.110	1.542	500	55	556.9	501.8	22.4
10	.105	1.615	345	36.2	538	486.9	22.1
11	.0195	1.665	233	4.5	491.4	482.1	21.9
12	.080	1.678	191	15.3	497.4	460.6	21.4
13	.1005	1.680	167	16.8	477.4	434.0	20.8
14	.101	1.680	142	14.3	448.3	407.0	20.2
15	.1015	1.667	120	12.2	419.2	380.6	19.5
16	.1045	1.622	93	9.7	390.3	351.7	18.8
17	.110	1.538	65	7.2	358.9	323.4	18.0
18	.067	1.485	-25.1	-1.7	321.7	301.4	17.3
19	.072	1.390	-108	-7.8	293.6	273.9	16.6
20	.075	1.342	-182	-13.7	260.2	242	15.5
21	.078	1.285	-250	-19.5	222.5	206.5	14.3
22	.082	1.229	-307	-25.2	181.3	167.5	12.9
23	.140	1.229	-307	-43.0	124.5	109.2	10.4
24	.140	1.229	-307	-43.0	66.2	58.1	7.6
25	.140	1.229	-307	-43.0	15.1	13.2	3.6
26	.140	1.229	-307	-43.0	-27.9	-24.5	-
27	.140	1.229	-307	-43.0	-27.9	-24.5	-

W = 20,000 Tons

10 Drags - 50 Tons each

f_g = 0.010

f_d = 0.500

Total Travel - 1117 Feet

Sources of Data for Analysis

The data on which the analyses of the variation of travel with different variables were based was collected at the Norfolk Naval Shipyard at the time of launching the USS SHANGRI-LA (CV38), which used seven clumps per side and the USS TARAWA (CV40), with five clumps per side. Hydraulic dynamometers were placed in six of the wires connecting the drag chain clumps to the vessel. The drags passed over three surfaces, rough concrete composed of concrete bearers with about six feet of soft earth between them, smooth slab concrete, and steel which covered the trigger pit. Tables III and IV are enclosed herewith, giving a summary of data taken from these dynamometers. Each clump weighed 50 tons.

Table V is a summary of the conditions at the time of launching of these vessels. Tables III, IV, and V, it is felt, fully justify the values of the different variables used in this thesis report. The ranges of the variables were selected from values referred to in the published literature on the subject.

For reference, the observed launching velocities of the USS SHANGRI-LA and USS TARAWA are shown in Curve VII as computed in the Norfolk Naval Shipyard.

TABLE III

USS SHANGRI-LA-CV38

Chain Drag Dynamometer Data

Rough Concrete

Drag No.	Energy Absorbed Ft.-Lb.	Effective Distance Ft.	Df_d Average	f_c Average
1 Port	16,464,000	282	58,383	0.521
1 Stbd	17,428,000	282	61,801	0.552
3 Port	14,060,000	230	61,130	0.546
3 Stbd	14,432,000	230	62,748	0.560
6 Port	2,720,000	52	52,307	0.467
6 Stbd	3,084,000	52	59,307	0.530
Totals	68,188,000	1,128	60,450	0.540

Smooth Concrete

Drag No.	Energy Absorbed Ft.-Lb.	Effective Distance Ft.	Df_d Average	f_c Average
1 Port	0	0	0	0
1 Stbd	0	0	0	0
3 Port	0	0	0	0
3 Stbd	0	0	0	0
6 Port	4,152,000	123	33,756	0.301
6 Stbd	4,420,000	123	35,935	0.321
Totals	8,572,000	246	34,846	0.311

Steel Cover of Trigger Pit

Drag No.	Energy Absorbed Ft.-Lb.	Effective Distance Ft.	Df_d Average	f_c Average
1 Port	558,000	25	22,320	0.199
1 Stbd	608,000	25	26,720	0.239
3 Port	580,000	25	23,200	0.207
3 Stbd	584,000	25	23,360	0.209
6 Port	0	0	0	0
6 Stbd	0	0	0	0
Totals	2,390,000	100	23,900	0.213

TABLE IV

USS TARAWA -CV38

Chain Drag Dynamometer Data

Rough Concrete

Drag No.	Energy Absorbed Ft.-Lb.	Effective Distance Ft.	Df_d Average	f_g Average
1 Port	23,610,000	389	60,700	0.542
1 Stbd	24,020,000	389	61,600	0.551
2 Port	19,800,000	315	62,900	0.562
2 Stbd	19,420,000	315	61,600	0.551
4 Port	9,150,000	173	53,000	0.473
4 Stbd	9,540,000	173	55,150	0.492
Totals	105,540,000	1,754	60,200	0.537

Smooth Concrete

Drag No.	Energy Absorbed Ft.-Lb.	Effective Distance Ft.	Df_d Average	f_g Average
1 Port	0	0	0	0
1 Stbd	0	0	0	0
2 Port	1,576,000	32	49,300	0.440
2 Stbd	1,389,000	32	43,400	0.387
4 Port	3,740,000	116	32,250	0.288
4 Stbd	3,935,000	116	33,920	0.303
Totals	10,640,000	296	35,960	0.321

Steel Cover of Trigger Pit

Drag No.	Energy Absorbed Ft.-Lb.	Effective Distance Ft.	Df_d Average	f_g Average
1 Port	892,500	28	31,900	0.284
1 Stbd	873,000	28	31,200	0.278
2 Port	845,000	28	30,150	0.269
2 Stbd	925,000	28	33,060	0.295
4 Port	740,000	28	26,410	0.236
4 Stbd	838,000	28	29,900	0.267
Totals	5,113,500	168	30,400	0.272

TABLE V

USS SHANGRI-LA Launching

OBSERVED DATA

Launching Wt. (Ship & Cradle) Tons		21088
C. G. Ship & Cradle Aft. of M. P.		14.32
Draft, Forward	Ft. & In.	14-1-7/8
Draft, Aft	Ft. & In.	21-11
Draft, Mean	Ft. & In.	18-0 7/16
Depth of Water Over Way Ends Ft.		15.86
Average Initial Pressure	Tons/Sq. Ft.	2.10
Travel to Pivot	Ft.	527
Pivoting Pressure	Tons	4140
Maximum Way End Pressure	Tons/Sq. Ft.	3.40
Travel to Maximum W. E. Pressure (Ft.)		320
Coefficient of Friction of Grease		.012
Coefficient of Friction of Concrete		.311
Coefficient of Friction Concrete Bearers and Gravel		.540
Coefficient of Friction Steel		.213
Keith's Coefficient of Water Resistance at 100% Buoyancy		1400
Maximum Velocity	Ft./Sec.	22.15
Travel to Max. Velocity	Ft.	390
Drop-Off Velocity	Ft./Sec.	15.3
Travel to Stop	Ft.	1110
Stern to Opposite Shore		544
F. P. from W. E.		197

TABLE V, CONT'D

GENERAL INFORMATION

Dimensions of Vessel

Length between Perpendiculars	820'-0"
Length Over All	888' - 9-1/8"
Beam, molded	93' - 0"
Breadth, Flight Deck	109' - 0"
Dead Rise	0' - 9"
Designer's L.W.L. (Above Bottom of Keel)	26' - 7-7/8"
Displacement (Designers L.W.L.)	33,500 Tons
Midship Section	Frame 102½
Frame Spacing	4' - 0"

Blocking

Type of Blocks	Collapsible
Material of Blocks	White Oak
Minimum Height	5' - 0" above 9/16" Declivity Line
Declivity of Keel	9/16"

Ground Ways

Length of Ground Ways, Over All	890' - 0"
Length of Ground Ways, from Face of Jack Log to Ways End	874' - 3"
Length of Ground Ways from Face of Jack Log to Face of Trigger	470' - 9"
Length of Ground Ways from Face of Trigger to End of Ways	403' - 6"
Declivity of Ways	9/16"/Ft.
Transverse Slope of Ways	3/8"/Ft.
Width of Ground Ways	7' - 2"
Material of Ground Ways	Long Leaf Yellow Pine
Spread of Ground Ways C to C	26' - 0"
Spread of Ground Ways R to R	33' - 2"

Sliding Ways

Forward End of Sliding Ways	Frame 7
After End of Sliding Ways	Frame 186½
Length of Sliding Ways, Over All	718' - 3½"
Length of Sliding Ways, Effective	716' - 0"
Length of Sliding Ways Forward of Trigger	467' - 2"

TABLE V, CONT'D

Sliding Ways, Cont'd.

Length of Sliding Ways Aft of Trigger	251' - 1½"
Width of Sliding Ways, Total	7' - 2"
Width of Sliding Ways, Effective	7' - 0"
Space Between Sliding Way and Ribband	1½"
Bearing Area Sliding Ways, Effective	10024 sq. ft.
Wedges, Number	726
Wedge Material	Oak
Wedge, Average Load Per	29.0 Tons
Grease Irons, Number	146
Grease Irons, Type	Steel, tapered
Grease Irons, Average Load Per	6.3 Tons.

Lubrication of Ways

(a)	Base Coat	Keystone, ½" thick
(b)	Slip Coat	Keystone, ¼" thick
(c)	Amount of Base Coat Applied	30,000#
(d)	Amount of Slip Coat Applied	15,600#
(e)	Amount of Base Coat Recovered	23,383#
(f)	Amount of Slip Coat Recovered	0

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